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## THE CLASSIFICATION OF THE POST-CRETACEOUS DEPOSITS.*

BY PROF. ANGELO HEILPRIN.

The point of first importance to determine is whether all the deposits succeeding the Cretaceous period belong to a single major system, or, as is generally recognized, to two distinct systems, the Tertiary and Quaternary of geologists. It will probably be conceded by all geologists that the only rational scheme of chronological classification is that which can be made to be of universal application; in other words, a system that applies equally to all countries. In our present knowledge, but one such scheme of broad classification is known—that which is based upon the rise and fall of successive faunas. Granting a nearly equivalent development of life-forms for the greater portion, if not the whole, of the earth's surface—a condition which can now be satisfactorily demonstrated, or at least demonstrated to a variation within narrow limits—it will be manifest that we have in this development a true guage of chronological relationship, and one that must be fairly exact in its application. The grouping of systems will then be a mere deduction from the time-record made to correspond to certain well-defined or rounded-off periods, so to speak, of faunal development, whose existence is made known to us through the dissimilarities of successive faunas.

How much, or what amount of, dissimilarity is considered sufficient to mark out distinct systems is a matter of little consequence to the geologist, but where uniformity of classification is required, naturally only equivalent terms, or terms of approximately equal value, should be used. The greater number of the major geological systems now recognized are delimited by faunal dissimilitudes of a more or less definite measure, which is indicated in the ratio of transgressional forms uniting to the system below and to that above. The present classification admits in a general way for each system a faunal peculiarity measured in its lowest terms by some 35 or 40 per cent, and this classification has fairly met the demands of geologists in its application to almost all the entire series of sedimentary rock deposits. Remarkably enough, in the case of the post-Cretaceous deposits, whose classification has been effected probably by greater niceties of percentage divisions than that of any other series, this measure has been only loosely, or not at all, adhered to. What, it might be asked, are the claims of the Post-Pliocene and recent formations to being considered a distinct system? Viewed in its faunal aspects, the question may be very readily disposed of: the formations in question have no claim to such recognition. If the formations from the Eocene to the Pliocene inclusive are justly considered to constitute, by virtue of their faunal unity, a distinct system, the Tertiary, then manifestly the post-Tertiary (Post-Pliocene to recent) must be a part of the same system, since its faunal ties unite it infinitely more closely with the more recent members of the Tertiary than the individual members of the latter are united among themselves. Thus the Eocene or Oligocene is further removed faunally from the Miocene than the Pleistocene is from the Pliocene; and the same relation holds with the Miocene and Pliocene. Lyell, himself the framer of the now very generally accepted classification ofthe post-Cretaceous deposits, admits that in the so-called Newer Pliocene deposits of Sicily the percentage of recent molluscan forms rises as high as 90, or even higher, consequently reducing the faunal peculiarity to less than 10 per cent. In the Chillesford beds of Suffolk, England, the faunal peculiarity is reduced to about 15 per cent, and in the Norwich or Fluvio-Marine Crag to 16 per cent. Again, the uppermost of the Subapennine deposits of Northern Italy, forming part of the "Astian" series (Pliocene proper of Capellini), have been shown by Foresti to hold about 80 per cent of living forms, reducing, therefore, the faunal peculiarity, in its lowest expression, to 20 per cent. On the other hand, the deposits immediately underlying these, forming still a part of the true Pliocene series—Foresti's horizon III—hold barely more than 43 per cent of living forms, and are thus strongly individualized by their faunal peculiarity, in so far, at least, as a relationship with the overlying deposits is concerned, although the ties with the deposits underlying (Mio–Pliocene of Capellini–Messinian of Mayer) are much more intimate. Horizon II of Foresti is characterized by some 39 per cent of living forms, and I by nearly 31 per cent; both of these divisions are by many Italian geologists classed with the Miocene, which really appears to be their true position, contrary stratigraphical evidence notwithstanding.

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Seeing how very closely the Pliocene fauna in its highest expression approximates the fauna of the present day (*et conseq.* the Post–Pliocene fauna), and the broad latitude of peculiarity allowed it by most geologists, it becomes interesting to inquire in how far similar conditions of relationship or divergence obtain among the older Tertiary deposits. It is well known to geologists that in most regions where Tertiary deposits are developed, the faunal relationship existing between the Eocene and Miocene series is a very restricted one; indeed, in some regions it would appear that there is scarcely a single species of fossil held in common by the two classes of deposits. This is very largely the case in France, and perhaps more particularly in the Eastern United States, where the respective faunas are practically wholly distinct. It is true that, in some regions, a careful analysis of the formations now frequently referred to the Oligocene has shown a number of connecting forms, and has brought the two formations in closer relationship with each other, but the uniting bond, as compared with that which unites the Pliocene with the Post-Pliocene, or the Tertiary with the post-Tertiary, is still very weak. In the Oligocene (Vicksburg) deposits of the United States, for example, it is doubtful if the number of transgressional forms uniting with the Miocene numbers more than six, and possibly not that many, out of a total of some 150 species.

These facts being admitted, it can scarcely be argued further that, with our existing classification as a basis, there remains any valid reason for separating, as a distinct system, the Post-Pliocene (post-Tertiary) series from the Tertiary (Pliocene). It may, however, still be contended that we allow too much latitude to the Pliocene, and that with a proper restriction to boundaries in which the recent faunal element does not exceed 70 or 75 per cent, instead of rising to 85 and 90, or more, room may be had for a major series with a largely peculiarized fauna. But even with this limitation the faunal break separating a post-Tertiary series from the upper member of the Tertiary (Pliocene), would scarcely be as great, and in most cases not nearly so great, as that separating the Pliocene from the Miocene, or the Miocene (or Oligocene) from the Eocene.

Apart from the matter of mere numbers as indicating a lack of of peculiarity in the post-Tertiary fauna, it may be urged that there are yet certain elements in it which serve broadly to distinguish it from the faunas immediately preceding, and which would entitle it to the claim of a true system-fauna. Thus, as has frequently been claimed, we have here the first evidences of man, and, therefore, the expression of a so-called "Psychozoic" era; the remains of a remarkable series of large edentate animals—*Megatherium, Mylodon, Megalonyx, Glyptodon, etc.*—foreign to the earlier faunas, yet sufficiently abundant as a distinguishing element in the fauna of later date; and finally, the elimination of certain faunal features of the period preceding, which can be passed over without further notice. As far as the occurrence of the giant Edentata and of certain other associated animal forms—*Toxodon, Macrauchenia*—is concerned, it may be remarked that by many geologists and paleontologists the beds containing their remains are referred to the Pliocene, and not to the Post-Pliocene, period; and we have now the unmistakable evidence of somewhat similar, or at least related, forms being found in the Miocene and Pliocene deposits of the Western United States. Nor, even if we admit that these remarkable forms are exclusively Post-Pliocene, can it be assumed that they are in themselves sufficient to distinguish a fauna, the less so as their remains have only been found in a comparatively limited portion of the earth's surface, and have yielded no substitutes elsewhere.

The case of man's appearance is equally inadmissible as a factor in the question, since, in the first place, it is now practically certain, even if positive proof in this direction is still wanting, that he already existed during the close of the Tertiary period, and not improbably even at a much earlier date. Furthermore, his advent, looked at purely from the zoological stand-point, could be no more a distinguishing feature in a fauna than would be the advent of *Dryopithecus* or *Hippopotamus*. Nothing can be more illogical than the assumption that because man is of all importance in the faunal element of to-day, judged from the stand-point of our own capricious opinions, he is of equal importance when measured by the purely zoological standard. Equally illogical is the assumption of a Psychozoic age as distinguished from any of the ages preceding.

Having, as I believe, satisfactorily shown that the Post-Pliocene series of deposits, which include the "Pleistocene," "Glacial" and "Recent" of most geologists, cannot be separated as a distinct system from the Tertiary, it becomes necessary to find a common name under which all these series of deposits can be included. The term Kainozoic (Cenozoic) or Tertiary, corresponding to Mesozoic or Secondary, and Palæozoic or Primary, might be conveniently retained, and its application so enlarged as to embrace both the Tertiary and Quaternary in use at present—Quaternary, of necessity, completely dropping away.

It now remains to determine of what relative values are the major divisions of the Kainozoic or Tertiary. It will probably be admitted by most geologists that the divisions pre-Glacial (Pleistocene), Glacial, and Recent are merely sub-groups of a single major formation, for which the familiar term Post-Pliocene might be conveniently retained. Its value may be accepted as being approximately equivalent to Pliocene, Miocene, Oligocene, or Eocene, although the values of these last differ somewhat among themselves. Indeed, it is not a little difficult to determine what precise significance is to be attached to these divisions of the Tertiary, whether they are of equivalent value with the (generally so considered) corresponding terms of the Mesozoic—Cretaceous, Jurassic, etc.—and Paleozoic series—Carboniferous, Devonian, etc—or not. In most geological tables they are accorded this value, but it is more than doubtful if they are entitled to it. Probably but few geologists will deny that the Post-Pliocene and Pliocene are much more intimately related to one another than are the Devonian and Silurian, the Devonian and Carboniferous, or the Jurassic and Cretaceous. And a similar intimate relation holds by comparison between the Eocene and Oligocene. The Post-Pliocene and Pliocene, again, appear in most cases to enjoy a much closer affiliation than exists between the latter and the Miocene, and similarly, the bond of union uniting the Eocene with the Oligocene is greater than that which holds the latter to the Miocene. So that while it may be impossible to attach absolute values to the terms or periods marked off in Tertiary chronology, it appears to the present writer more in consonance with existing facts, and as a stricter parallel to the methods employed in pre-Tertiary terminology, to group the entire series into three main sections, corresponding to as many periods of geological time, as follows:

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|---|---|---|
| KAINOZOIC or TERTIARY | NEOGENE | Post-Pliocene.<br>Pliocene. |
| | METAGENE | Miocene. |
| | EOGENE | Oligocene.<br>Eocene. |

The classification of the Tertiary deposits, brought *en rapport* with the classification of the pre-Tertiary series, and as based upon the formations of the Atlantic slope of the United States, would then be as follows:

| | | | |
|---|---|---|---|
| Kainozoic or Tertiary | Neogene. | Post-Pliocene | Recent.<br>Glacial.<br>Pleistocene. |
| | | Pliocene. | Floridian. |
| | Metagene. | Miocene. | Carolinian<br>Virginian.<br>Marylandian. |
| | Eogene. | Oligocene. | Orbitoitic (Vicksburg) |
| | | Eocene. | Jacksonian.<br>Claibornian.<br>Buhrstone.<br>Eo-Lignitic. |
| Mesozoic or Secondary. | Cretaceous. | Chalk. (European.)<br>Gault. | Danian.<br>Senonian.<br>Turonian.<br>Cenomanian.<br>Albian.<br>Neocomian. |
| | Jurassic. | Oolite.<br>Lias. | &c.<br>&c. |
| | Triassic. | | &c. |

*On the value of the faunal element in geological chronology.* Some geologists, and notably those who profess but little knowledge of paleontology, have attempted to make light of the evidence which the zoological record brings to bear upon the classification of rock-masses. Indeed, even at the present time, in some of our surveys only a left-handed assistance is asked by the geologist-in-charge from the paleontologist, with the result known to all who are capable of distinguishing between work that is done and that which still requires to be done. It is true that in many tracts, and in tracts even of wide area, the relative sequence of rock formations can frequently be traced without the aid of paleontology, and a map, more or less perfect, constructed on the details thus brought together. But soooner or later, if the comparative study of a region is necessitated, reference must be had to the fossil remains, which alone serve to the geologist the data of an infallible chronology. The absolute succession of equivalent faunas, or faunas of a practically identical facies, which has been demonstrated for the greater part of the world, clearly establishes the claims of the faunal element as the *guide propre* in the determination of chronology. It not only serves to fix the relative sequence of formations for any one country, but determines absolutely the position in time which these formations occupy in a geological scale constructed for the entire world.

It is, however, contended, and apparently with force, that certain physical phenomena associated with the disposition of rock-masses are as clearly consecutive in their occurrence as is the progression of the life series, and might, hence, claim equal importance as chronological determinants of the geological scale. Thus, it is pointed out, we have the world over a physical break of definite importance between the Paleozoic and Mesozoic series of rocks, and a somewhat similar break—wanting in some parts—between the Mesozoic and Kainozoic; and, again, minor breaks between the lesser formations. But how could the equivalence of these breaks be determined were it not for the predetermination of age through the faunal remains? It might be assumed, where a deposit of a definite or special lithological character can be continuously followed, such as coal or the chalk of the Cretaceous period, that we are furnished with certain distinctive data which here preclude the possibility of mistaking the actual equivalence; that, for example, where we recognize the break following the chalk in England we recognize a similar break in France and Belgium, and likewise the same for the coal. But by what method, other than the paleontological one, could the post-Cretaceous break be identified or correlated in regions, such as the Eastern United States, where the true chalk is wanting, and where the beds representing it could, from lithological character, about as well be taken to represent an older member of the series to which they belong as a newer one?

The notion held by some geologists that the true determinants of a formation—or, more properly speaking, the true measure of geological time, is found rather in the lithological than in the paleontological record, can not for a moment stand the test of a logical inquiry. To submit, for example, that the matter of continuous sedimentation, or the absence or presence of conformability, or the existence or non-existence of a physical (lithological) break, can in any way affect a time-record based upon the uninterrupted succession of progressive faunas, requires for its acceptance facts of a very different character from any that geology has thus far brought forward. It is true that geologists may have erred in locating or defining their time-periods (or formations), and, doubtless, more accurate research will alter, or completely obliterate, much that has been done in the way of chronological classification, but to maintain, as some geologists would lead us to believe, that the Cretaceous and Tertiary formations (or periods) no longer exist as such by virtue of the discovery of a series of intermediate connecting beds; or that, for a somewhat similar rêason, the Oligocene formation has given up its right to existence independently of the Eocene, is maintaining a position which no geologist who has examined into the premises will be willing to concede. We may as well admit that the various periods recognized in human history do not exist because they can be continuously traced without break of any kind; and similarly, centuries and years have no existence because they are continuously consecutive. The geologist should bear in mind that the time-periods (*et conseq.* the corresponding formations) are artificial constructions based upon equivalent phenomena for the entire world, and serve only for the purpose of a universal classification. The finding of an intermediate formation (period) in no way obliterates the formations between which it may have been found, provided the limits of these formations have been satisfactorily determined; for example, the discovery of a connecting series of deposits between the true Cretaceous and Tertiary, uniting them by way of continuous sedimentation, does *not* render the entire series Cretaceo-Tertiary, but the connecting beds are *alone* entitled to this designation. The Cretaceous and Tertiary sections of the series remain as truly Cretaceous and Tertiary in a general scheme of classification as they were before the intermediate beds were discovered. Manifestly, in a complete geological scale, whose near realization is by no means impossible, all the various formations now recognized will be found united to one another through the intermedium of connecting beds, but certainly no geologist will go so far as to urge that, for this reason, a classification of time, based upon some artificial basis of chronology, will no longer be necessary or desirable.

It has also recently been objected that a classification based upon percentages of survivals is an absurdity, and wholly illogical. Why illogical, it might be asked? Surely, if there has been a general, and nearly equivalent, faunal succession or development for the world at large—a condition which can be clearly demonstrated—then, manifestly, the ratio of survivals must be a definite measure of this development; and if this is the case, it must, necessarily, prove the safest guide in the delimitation of chronological boundaries. Were it possible to definitely determine the proportion of survivals, or what is practically equivalent to the same thing, determine the amount of actual faunal peculiarities, by specific determinations made with equal care for all countries, we would then have, and only then, a rational basis for a systematic classification applicable to the whole world.